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2Physics Quote:
"The High Precision QCD (HPQCD) Collaboration has now determined the mass of the strange quark to an accuracy of better than 2%, which improves on the evaluation of previous results given in the Particle Data Tables by a factor of 10."
-- Christine Davies (Read her article: **"Weighty Matters for Particle Physics"**)

Tuesday, October 05, 2010

Physics Nobel Prize 2010: Graphene


Andre Geim (photo courtesy: Sergeom, Wikimedia Commons) and Konstantin Novoselov (photo courtesy: University of Manchester, UK)

The Nobel Prize in Physics 2010 was awarded jointly to Andre Geim and Konstantin Novoselov of the University of Manchester "for groundbreaking experiments regarding the two-dimensional material graphene"

Graphene is a form of carbon. As a material it is completely new – not only the thinnest ever but also the strongest. As a conductor of electricity it performs as well as copper. As a conductor of heat it outperforms all other known materials. It is almost completely transparent, yet so dense that not even helium, the smallest gas atom, can pass through it. Carbon, the basis of all known life on earth, has surprised us once again.

Homepage of Andre Geim >> **Homepage of Konstantin Novoselov >>**
Link to the Mesoscopic Physics Group, University of Manchester, UK >>

Geim and Novoselov extracted the graphene from a piece of graphite such as is found in ordinary pencils. Using regular adhesive tape they managed to obtain a flake of carbon with a thickness of just one atom. This at a time when many believed it was impossible for such thin crystalline materials to be stable.

However, with graphene, physicists can now study a new class of two-dimensional materials with unique properties. Graphene makes experiments possible that give new twists to the phenomena in quantum physics. Also a vast variety of practical applications now appear possible including the creation of new materials and the manufacture of innovative electronics. Graphene transistors are predicted to be substantially faster than today's silicon transistors and result in more efficient computers.

Since it is practically transparent and a good conductor, graphene is suitable for producing transparent touch screens, light panels, and maybe even solar cells.

When mixed into plastics, graphene can turn them into conductors of electricity while making them more heat resistant and mechanically robust. This resilience can be utilised in new super strong materials, which are also thin, elastic and lightweight. In the future, satellites, airplanes, and cars could be manufactured out of the new composite materials.

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This year's Laureates have been working together for a long time now. Konstantin Novoselov, 36, first worked with Andre Geim, 51, as a PhD-student in the Netherlands. He subsequently followed Geim to the United Kingdom. Both of them originally studied and began their careers as physicists in Russia. Now they are both professors at the University of Manchester.

Playfulness is one of their hallmarks, one always learns something in the process and, who knows, you may even hit the jackpot. Like now when they, with graphene, write themselves into the annals of science.

Labels: **Condensed Matter 2**, **Nanotechnology 2**, **Nobel Prize**

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*posted by Quark @ **7:24 AM***   **links to this post**

Sunday, October 03, 2010

Upcoming Physics Conferences

[To add an upcoming physics conference to this list, please send an email to **2Physics@gmail.com**]

Oct 18-23: **4th Intl Symposium "High Energy Physics, Cosmology and Gravity"** (Kyiv, Ukraine)
Oct 23-28: **New Trends in Nonlinear Dynamics: Heat Control and Thermo-electric Efficiency**(Erice, Sicily, Italy)
Nov 01-06: **Petrov 2010 Anniversary Symposium on General Relativity and Gravitation** (Kazan, Russia)
Nov 01-07: **Finsler Extensions of Relativity Theory** (Moscow, Russia)
Nov 03-05: **12th WSEAS Intl Conference on Mathematical and Computational Methods in Science and Engineering** (Faro, Portugal)
Nov 03-05: **3rd WSEAS Intl Conference on Materials Science** (Faro, Portugal)
Nov 17-19: **International Conference on Two Cosmological Models** (Mexico City, Mexico)
Feb 16-18: **Foundational Aspects of Cosmology** (Hamburg, Germany)
May 02-06: **5th Feynman Festival** (Guarujá or Foz de Iguaçu, Brazil)
May 02-06: **12th Intl Conference on Squeezed States and Uncertainty Relations** (Guarujá or Foz de Iguaçu, Brazil)
May 16-18: **Intl Symposium on Photonics and Optoelectronics** (Wuhan, China)
May 30- June 03: **8th Alexander Friedmann Intl Seminar on Gravitation and Cosmology** (with a Satellite symposium devoted to the Casimir effect) (Rio de Janeiro, Brazil)
Jul 24-30: **19th International Conference on Composites or Nano Engineering** (Shanghai, China)
Aug 07-13: **Quantum Theory and Symmetries** (Prague, Czech Republic)

Labels: **Conferences**

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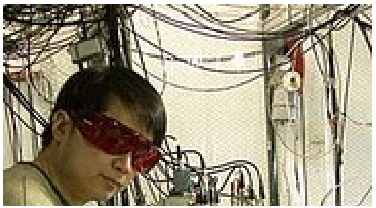
Sunday, September 26, 2010

Aluminum Atomic Clocks Reveal Einstein's Relativity at a Personal Scale



James Chin-wen Chou with the world's most precise clock, based on the vibrations of a single aluminum ion. The ion is trapped inside the metal cylinder (center right) [Photo credit: J. Burrus/NIST]

Scientists have known for decades that time

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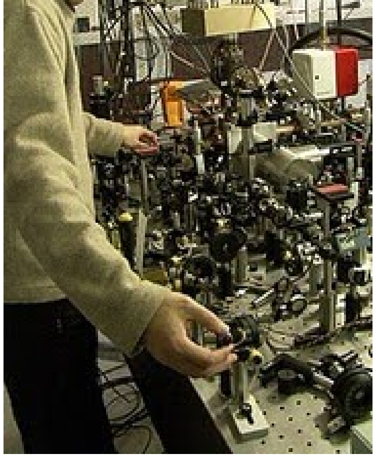

passes faster at higher elevations—a curious aspect of Einstein's theories of relativity that previously has been measured by comparing clocks on the Earth's surface and a high-flying rocket.

Now, physicists at the National Institute of Standards and Technology (NIST) have measured this effect at a more down-to-earth scale of 33 centimeters, or about 1 foot, demonstrating, for instance, that you age faster when you stand a couple of steps higher on a staircase.

Described in the Sept. 24 issue of Science [1], the difference is much too small for humans to perceive directly—adding up to approximately 90 billionths of a second over a 79-year lifetime—but may provide practical applications in geophysics and other fields.

Similarly, the NIST researchers observed another aspect of relativity—that time passes more slowly when you move faster—at speeds comparable to a car travelling about 20 miles per hour, a more comprehensible scale than previous measurements made using jet aircraft.

NIST scientists performed the new "time dilation" experiments by comparing operations of a pair of the world's best experimental atomic clocks. The nearly identical clocks are each based on the "ticking" of a single aluminum ion (electrically charged atom) as it vibrates between two energy levels over a million billion times per second. One clock keeps time to within 1 second in about 3.7 billion years (Read past 2Physics report: **World's Most Precise Clock : NIST Developed Second 'Quantum Logic Clock' Based on Aluminum Ion**) and the other is close behind in performance. The two clocks are located in different laboratories at NIST and connected by a 75-meter-long optical fiber.

NIST's aluminum clocks—also called "quantum logic clocks" because they borrow logical decision-making techniques from experimental quantum computing—are precise and stable enough to reveal slight differences that could not be seen until now. The clocks operate by shining laser light on the ions at optical frequencies, which are higher than the microwave frequencies used in today's standard atomic clocks based on the cesium atom. Optical clocks could someday lead to time standards 100 times more accurate than today's standard clocks.

The aluminum clocks can detect small relativity-based effects because of their extreme precision and high "Q factor"—a quantity that reflects how reliably the ion absorbs and retains optical energy in changing from one energy level to another—says NIST postdoctoral researcher James Chin-Wen Chou, first author of the paper.

"We have observed the highest Q factor in atomic physics," Chou says. "You can think about it as how long a tuning fork would vibrate before it loses the energy stored in the resonating structure. We have the ion oscillating in sync with the laser frequency for about 400 thousand billion cycles."

The NIST experiments focused on two scenarios predicted by Einstein's theories of relativity. First, when two clocks are subjected to unequal gravitational forces due to their different elevations above the surface of the Earth, the higher clock—experiencing a smaller gravitational force—runs faster. Second, when an observer is moving, a stationary clock's tick appears to last longer, so the clock appears to run slow. Scientists refer to this as the "twin paradox," in which a twin sibling who travels on a fast-moving rocket ship would return home younger than the other twin. The crucial factor is the acceleration (speeding up and slowing down) of the travelling twin in making the round-trip journey.

NIST scientists observed these effects by making specific changes in one of the two aluminum clocks and measuring the resulting differences in the two ions' relative ticking rates, or frequencies.

Cartoon credit: Loel Barr of NIST

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In one set of experiments, scientists raised one of the clocks by jacking up the laser table to a height one-third of a meter (about a foot) above the second clock. Sure enough, the higher clock ran at a slightly faster rate than the lower clock, exactly as predicted.

The second set of experiments examined the effects of altering the physical motion of the ion in one clock. (The ions are almost completely motionless during normal clock operations.) NIST scientists tweaked the one ion so that it gyrated back and forth at speeds equivalent to several meters per second. That clock ticked at a slightly slower rate than the second clock, as predicted by relativity. The moving ion acts like the traveling twin in the twin paradox.

Such comparisons of super-precise clocks eventually may be useful in geodesy, the science of measuring the Earth and its gravitational field, with applications in geophysics and hydrology, and possibly in space-based tests of fundamental physics theories, suggests physicist Till Rosenband, leader of NIST's aluminum ion clock team.

NIST scientists hope to improve the precision of the aluminum clocks even further, as much as 10-fold, through changes in ion trap geometry and better control of ion motion and environmental interference. The aim is to measure differences in timekeeping well enough to measure heights to an accuracy of 1 centimeter, a performance level suitable for making geodetic measurements. The paper suggests that optical clocks could be linked to form a network of "inland tidal gauges" to measure the distance from the earth's surface to the geoid (the surface of the earth's gravity field that matches the global mean sea level). Such a network could be updated far more frequently than current techniques.

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[We thank National Institute of Standards and Technology, Boulder, CO for materials used in this report]

Labels: **Einstein**, **Precision Measurement**

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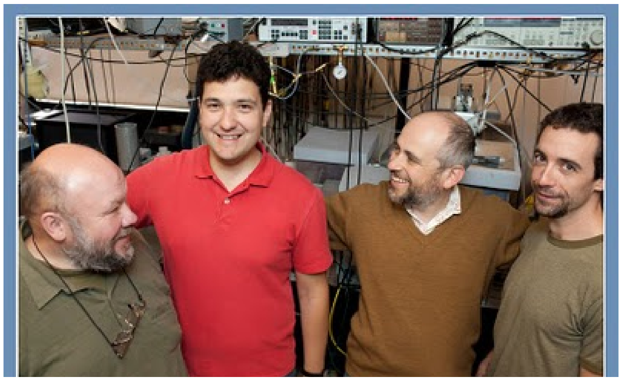
*posted by Quark @ **10:26 PM*** **links to this post**

Sunday, September 19, 2010

"Spin Doctors" Build a Better Magnetometer



(From left to right) Mikhail Balabas, Todor Karaulanov, Dmitry Budker, and Micah Ledbetter in Budker's laboratory in University of California, Berkeley [Photo credit: Damon English, Lawrence Berkeley National Laboratory]

Magnetometers come in many shapes and sizes – an ordinary hand-held

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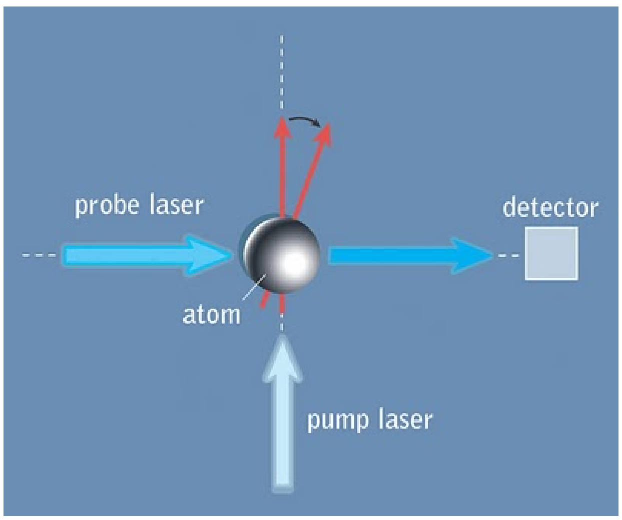
compass is the simplest – but alkali-vapor magnetometers are extrasensitive devices that measure magnetic fields using light and atoms. They can detect archaeological remains and mineral deposits underground by their faint magnetic signatures, among a host of other scientific applications.

Researchers from the U.S. Department of Energy's Lawrence Berkeley National Laboratory, the University of California at Berkeley, and the Vavilov State Optical Institute in St. Petersburg, Russia, have now made sensitive measurements of magnetic fields by maintaining the spin polarization of atoms in an alkali-vapor magnetometer for more than 60 seconds at room temperature – a two-orders-of-magnitude improvement in this important measurement parameter over the best previous performance [1].

In a spin-polarized population of atoms, more than half the atoms are oriented in the same direction. An alkali-vapor magnetometer polarizes a vapor of alkali-metal atoms, for example potassium, rubidium, or cesium, inside a glass cell using a circularly-polarized "pump" laser beam.

Because the spinning atoms have a magnetic moment (with north and south magnetic poles, like a bar magnet), an outside magnetic field will tilt the axis of spin and cause it to precess like a spinning top that's been pushed off the vertical. Changes in the outside field's strength or direction can be detected using a probe laser to repeatedly measure the vapor's average spin orientation.



In a vapor-cell magnetometer, the spin of a population of atoms is first polarized, as indicated by the vertical red arrow, by a pump laser that is itself circularly polarized. When a magnetic field is applied, the spin vector is rotated, as indicated by the tilted red arrow. (The magnetic field is perpendicular to the plane of this diagram.) The probe laser's own plane polarization is rotated by the atom's spin, and the degree of rotation is measured at the detector **In a vapor-cell magnetometer, the spin of a population of atoms is first polarized, as indicated by the vertical red arrow, by a pump laser that is itself circularly polarized. When a magnetic field is applied, the spin vector is rotated, as indicated by the tilted red arrow. (The magnetic field is perpendicular to the plane of this diagram.) The probe laser's own plane polarization is rotated by the atom's spin, and the degree of rotation is measured at the detector.** **[Image courtesy: Lawrence Berkeley National Laboratory]**

"The fundamental sensitivity of the measurement depends on a number of variables," says Dmitry Budker of Berkeley Lab's Nuclear Science Division, a professor of physics at UC Berkeley. "These include the number of atoms in the sample and, most important, the spin relaxation time of the polarized atoms."

Spin relaxation is the loss of polarization, the return of the population of atoms to random orientations, which happens faster as atoms collide with other atoms, or if the external magnetic field varies.

How to keep 'em spinning

"When an alkali-metal atom bounces off a glass wall, it tends to stick for a little while," says Budker. "During its stay it is subject to fluctuating magnetic fields, which cause it to lose polarization. So one way to maintain polarization is to keep the atoms away from the wall, or to make their sojourns on the wall shorter."

One approach is to fill the cell with an inert buffer gas like helium or neon,

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at a density high enough that the alkali atoms constantly bump into the buffer gas atoms instead of colliding with the walls. The resulting slow diffusion keeps many of the polarized atoms away from the wall for a long time. Nevertheless, collisions with the buffer gas atoms eventually relax the polarization of the metal atoms.

(From left to right) Mikhail Balabas, Todor Karaulanov, Micah Ledbetter, and Dmitry Budker with the antirelaxation-coated vapor cell. Inset shows the rubidium reservoir and the lock (red) that can open or close off the interaction area in the bulb [Photo credit: Damon English, Lawrence Berkeley National Laboratory]

A better way to keep spin coherence high is to coat the interior of the glass vapor cell with an "antirelaxation" coating. The goal is to increase the number of bounces an atom can survive before losing its polarization.

"It's important to reduce magnetic fluctuations by avoiding any heavy atoms in the coating," Budker says. Compounds of light carbon and hydrogen atoms are the choice; state-of-the-art antirelaxation coatings are paraffins, known chemically as alkanes. A polarized atom can hit a paraffin coating 10,000 times before losing its polarization.

But Budker and his long-time colleague Mikhail Balabas of St. Petersburg's Vavilov State Optical Institute have worked to extend relaxation times using different coatings. Contrary to conventional wisdom, Balabas suggested substituting a different kind of hydrocarbon known as an alkene, or olefin. Alkenes are similar to alkanes but, instead of being saturated (all single bonds), have one carbon double bond in the molecule. The researchers' experiments with rubidium vapor cells subsequently showed that a polarized rubidium atom could bounce off an alkene coating a million times before losing its polarization.

Fine-tuning the experiment

"The coating material is not all there is to prolonging polarization, however," Budker says. "One way polarization is lost is when polarized rubidium atoms in the cell get in contact with uncoated surfaces in the cell's rubidium reservoir – the sidearm that contains a droplet of the solid metal."
Balabas devised a simple lock – a sliding glass plug that, merely by rotating the cell assembly, opens or closes the stem between the reservoir and the interaction region where the atoms are polarized and measured.

Finally, the researchers slowed spin relaxation due to collisions among the rubidium atoms inside the interaction area of the cell by modifying a technique called SERF (for "spin exchange, relaxation-free" [2]). The physics of SERF were developed by William Happer and applied to magnetometry by Michael Romalis, both of Princeton University. SERF normally uses buffer gas to reduce the number of alkali atoms hitting the cell wall, while at the same time paradoxically stepping up collisions among the alkali atoms themselves, heating the cell to some 150 degrees Celsius and increasing the density of the atomic vapor.

SERF works only for very weak magnetic fields, where precession is slow. Since atoms collide many times during any period of precession, the multiple collisions frequently exchange spin states among the atoms and keep the average polarization high. To extend the relaxation time still further, the Berkeley and Vavilov Institute collaboration used their "super" antirelaxation coating instead of the usual buffer gas.

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The experimental setup was built in Budker's laboratory by Micah Ledbetter and Todor Karaulanov, and was designed to maintain fine control over the shape of magnetic fields inside the experimental chamber. The vapor cell was shielded from Earth's magnetic field by four layers of mu metal, an alloy of nickel and iron that shunts magnetic fields around the shielded area, plus a cylinder of ceramic ferrite.

The experimental assembly was gimbaled so the vapor cell could be rotated, letting the sliding plug lock the neck of the flask or unlock it to allow rubidium vapor into the reaction region. Then a circularly polarized pump beam traversed the axis of the experiment to polarize the atomic vapor, while a probe beam passing through the cell from side to side recorded the spin state of the rubidium vapor by measuring how the probe beam's own linear polarization was rotated.

Three cells were tested, which differed either in construction or in the rubidium isotopes they contained. Relaxation times in two of the cells were about 15 seconds, already a significant extension, but in one, using the most common isotope of rubidium, 85Rb, the relaxation time stretched to over a minute. In contrast to the usual SERF setup, this very long relaxation time was achieved at room temperature instead of extreme heat.

"We have demonstrated two orders of magnitude improvement over the best paraffin coatings, and at room temperature – but at a relatively low magnetic field," Budker says. "The next challenge is to use this technique in stronger magnetic fields – as strong as Earth's magnetic field, for example, where many of the practical applications are."

At the same time, Budker and his colleagues intend to explore the application of their new coatings, and the other tricks they used to achieve long relaxation times, to devices other than magnetometers. Among the candidates are atomic clocks, quantum memory devices, and other scientific gadgets that likewise depend on long-lived spin polarization of atoms.

An early exploration of how vapor-cell wall coatings increase spin relaxation, "Relaxation of optically pumped Rb atoms on paraffin-coated walls," by French physicists Marie-Anne Bouchiat and Jean Brossel, was published in 1966 in Physical Review [3]. A more recent "Investigation of anti-relaxation coatings for alkali-metal vapor cells using surface science techniques" was conducted by Budker and colleagues including Balabas, Bouchiat, Karaulanov, Alex Pines, and others, and is available online [4].

Reference:
[1] Mikhail Balabas, Todor Karaulanov, Micah Ledbetter, Dmitry Budker, "Polarized Alkali-Metal Vapor with Minute-Long Transverse Spin-Relaxation Time", Phys. Rev. Lett, 105, 070801 (2010). **Abstract**. **arXiv:1005.1617**.
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[This article is written by Paul Preuss of Lawrence Berkeley National Laboratory, USA]

Labels: **Atomic Physics 3**

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*posted by Quark @ **5:52 PM*** **links to this post**

Sunday, September 12, 2010

New Physics from Graphene Quartet's Quantum Harmonies

Joseph Stroscio [Photo courtesy: Center for Nanoscale Science & Technology (CNST), Gaithersburg, MD, USA]

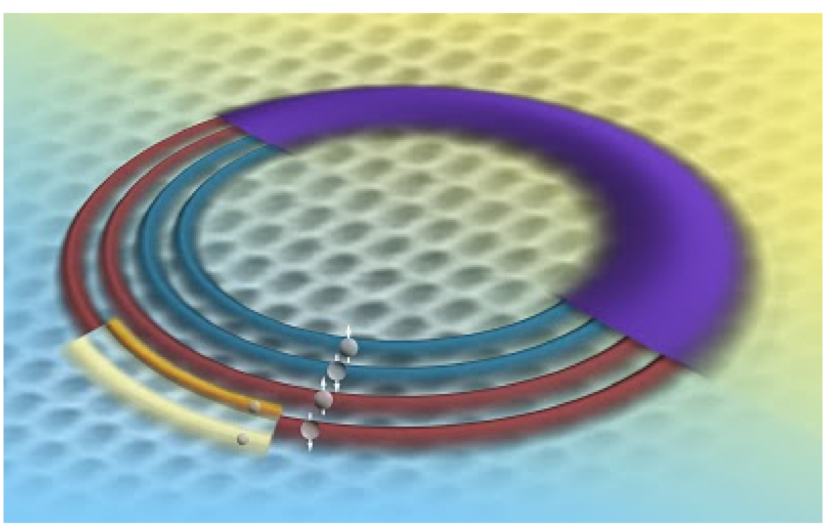
An international team of researchers from the National Institute of Standards and Technology (NIST), the University of Maryland, Seoul National University, the Georgia Institute of Technology, and the University of Texas at Austin, have "unveiled" a quartet of graphene's electron states and discovered that electrons in graphene can split up into an unexpected and tantalizing set of energy levels when exposed to extremely low temperatures and extremely high magnetic fields.

The team, led by Joseph Stroscio of the Electron Physics Group in the NIST Center for Nanoscale Science and Technology (CNST), published their results in Sept. 9, 2010, issue of Nature [1]. The new research raises several intriguing questions about the fundamental physics of this exciting material and reveals new effects that may make graphene even more powerful than previously expected for practical applications.

Graphene is one of the simplest materials—a single-atom-thick sheet of carbon atoms arranged in a honeycomb-like lattice—yet it has many remarkable and surprisingly complex properties. Measuring and understanding how electrons carry current through the sheet is important to realizing its technological promise in wide-ranging applications, including high speed electronics and sensors. For example, the electrons in graphene act as if they have no mass and are almost 100 times more mobile than in silicon. Moreover, the speed with which electrons move through graphene is not related to their energy, unlike materials such as silicon where more voltage must be applied to increase their speed, which creates heat that is detrimental to most applications.

To fully understand the behavior of graphene's electrons, scientists must study the material under an extreme environment of ultra-high vacuum, ultra-low temperatures and large magnetic fields. Under these conditions, the graphene sheet remains pristine for weeks, and the energy levels and interactions between the electrons can be observed with precision [2].

NIST recently constructed the world's most powerful and stable scanning-probe microscope, with an unprecedented combination of low temperature (as low as 10 millikelvin, or 10 thousandths of a degree above absolute zero), ultra-high vacuum and high magnetic field. In the first measurements made with this instrument, the team has used its power to resolve the finest differences in the electron energies in graphene, atom-by-atom.



[Image credit: T. Schindler and K. Talbott/NIST] This artist's rendition illustrates the electron energy levels in graphene as revealed by a unique NIST instrument. Because of graphene's properties, an electron in any given energy level (the wide, purple band)

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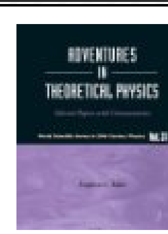

comprises four quantum states (the four rings), called a "quartet." This quartet of levels split into different energies when immersed in a magnetic field. The two smaller bands on the outermost ring represent the further splitting of a graphene electronic state.

"Going to this resolution allows you to see new physics," said Young Jae Song, a postdoctoral researcher who helped develop the instrument at NIST and make these first measurements.

And the new physics the team saw raises a few more questions about how the electrons behave in graphene than it answers.

Because of the geometry and electromagnetic properties of graphene's structure, an electron in any given energy level populates four possible sublevels, called a "quartet." Theorists have predicted that this quartet of levels would split into different energies when immersed in a magnetic field, but until recently there had not been an instrument sensitive enough to resolve these differences.

"When we increased the magnetic field at extreme low temperatures, we observed unexpectedly complex quantum behavior of the electrons," said NIST Fellow Joseph Stroscio.

What is happening, according to Stroscio, appears to be a "many-body effect" in which electrons interact strongly with one another in ways that affect their energy levels.

One possible explanation for this behavior is that the electrons have formed a "condensate" in which they cease moving independently of one another and act as a single coordinated unit.

"If our hypothesis proves to be correct, it could point the way to the creation of smaller, very-low-heat producing, highly energy efficient electronic devices based upon graphene," said Shaffique Adam, a postdoctoral researcher who assisted with theoretical analysis of the measurements.

The group's work was also recently featured in another paper in Nature Physics [3], in which they describe how the energy levels of graphene's electrons vary with position as they move along the material's crystal structure. The way in which the energy varies suggests that interactions between electrons in neighboring layers may play a role.

References

[1] Y.J. Song, A.F. Otte, Y. Kuk, Y.Hu, D.B. Torrance, P.N. First, W.A. de Heer, H. Min, S. Adam, M.D. Stiles, A.H. MacDonald and J.A. Stroscio, "High Resolution Tunnelling Spectroscopy of a Graphene Quartet", Nature, 467, 185–189 (09 September, 2010). **Abstract**.
[2] D.L. Miller, K.D. Kubista, G.M. Rutter, M. Ruan, W.A. de Heer, P.N. First and J.A. Stroscio. "Observing the quantization of zero mass carriers in graphene". Science, 324, 924 - 927 (May 15, 2009). **Abstract**.
[3] D.L. Miller, K.D. Kubista, G.M. Rutter, Ming Ruan, W.A. de Heer, M. Kindermann, P.N. First and J.A. Stroscio, "Real-space mapping of magnetically quantized graphene states", Nature Physics. Published online Aug. 8, 2010. doi:10.1038/nphys1736. **Abstract**.

Labels: **Nanotechnology 2**

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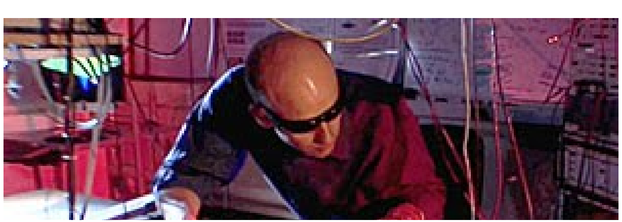
posted by Quark @ ***9:41 PM*** **links to this post**

Sunday, September 05, 2010

'Quantum Cats' Made of Photons



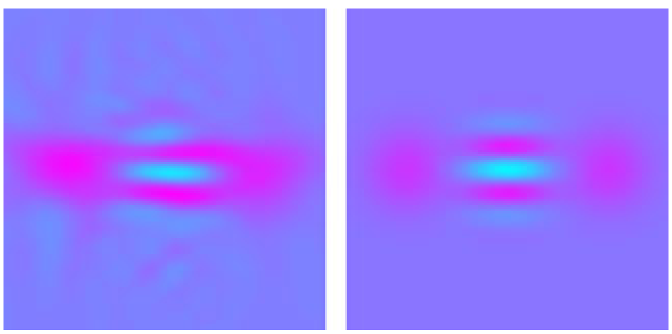
NIST research associate Thomas Gerrits at the laser table used to create "quantum cats" made of photons [Photo courtesy: NIST, Boulder, CO, USA]

Researchers at the National Institute of Standards and Technology (NIST) have created "quantum cats" made of photons (particles of light), boosting prospects for manipulating light in new ways to enhance precision measurements as well as computing and communications based on quantum physics.

The NIST experiments, described in a forthcoming paper in Physical Review A, repeatedly produced light pulses that each possessed two exactly opposite properties—specifically, opposite phases, as if the peaks of the light waves were superimposed on the troughs. Physicists call this an optical Schrödinger's cat. NIST's quantum cat is the first to be made by detecting three photons at once and is one of the largest and most well-defined cat states ever made from light. (Larger cat states have been created in different systems by other research groups, including one at NIST.)

A "cat state" is a curiosity of the quantum world, where particles can exist in "superpositions" of two opposite properties simultaneously. Cat state is a reference to German physicist Erwin Schrödinger's famed 1935 theoretical notion of a cat that is both alive and dead simultaneously.

"This is a new state of light, predicted in quantum optics for a long time," says NIST research associate Thomas Gerrits, lead author of the paper. "The technologies that enable us to get these really good results are ultrafast lasers, knowledge of the type of light needed to create the cat state, and photon detectors that can actually count individual photons."



These colorized plots of electric field values indicate how closely the NIST "quantum cats" (left) compare with theoretical predictions for a cat state (right). The purple spots and alternating blue contrast regions in the center of the images indicate the light is in the appropriate quantum state [Image credit: Thomas Gerrits/NIST]

The NIST team created their optical cat state by using an ultrafast laser pulse to excite special crystals to create a form of light known as a squeezed vacuum, which contains only even numbers of photons. A specific number of photons were subtracted from the squeezed vacuum using a beam splitter. The photons were identified with a NIST sensor that efficiently detects and counts individual photons [2]. Depending on the number of subtracted photons, the remaining light is in a state that is a good approximation of a quantum cat says Gerrits—the best that can be achieved because nobody has been able to create a "real" one, by, for instance, the quantum equivalent to superimposing two weak laser beams with opposite phases.

NIST conducts research on novel states of light because they may enhance measurement techniques such as interferometry, used to measure distance based on the interference of two light beams. The research also may contribute to quantum computing—which may someday solve some problems that are intractable today—and quantum communications, the most secure method known for protecting the privacy of a communications channel. Larger quantum cats of light are needed for accurate information processing.

References

[1] T. Gerrits, S. Glancy, T. Clement , B. Calkins, A. Lita, A. Miller, A. Migdall, S.W. Nam, R. Mirin and E. Knill, "Generation of optical coherent state superpositions by number-resolved photon

subtraction from squeezed vacuum", Physical Review A. Accepted for publication.
Abstract: We have created heralded coherent state superpositions (CSS), by subtracting up to three photons from a pulse of squeezed vacuum light. To produce such CSSs at a sufficient rate, we used our high-efficiency photon-number-resolving transition edge sensor to detect the subtracted photons. This is the first experiment enabled by and utilizing the full photon-number-resolving capabilities of this detector. The CSS produced by three-photon subtraction had a mean photon number of 2.75 (errorbar: -0.24+0.06) and a fidelity of 0.59 (errorbar: -0.14+0.04) with an ideal CSS. This confirms that subtracting more photons results in higher-amplitude CSSs.
[2] A. E. Lita, B. Calkins, L. A. Pellouchoud, A. J. Miller, S. Nam, "Superconducting transition-edge sensors optimized for high-efficiency photon-number resolving detectors", Proc. SPIE, Vol. 7681, 76810D (2010); doi:10.1117/12.852221. **Abstract**.

[We thank National Institute of Standards and Technology, Boulder, CO, USA for materials used in this posting]

Labels: **Quantum Computation and Communication 3**

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*posted by Quark @ **8:44 AM*** **links to this post**

Sunday, August 29, 2010

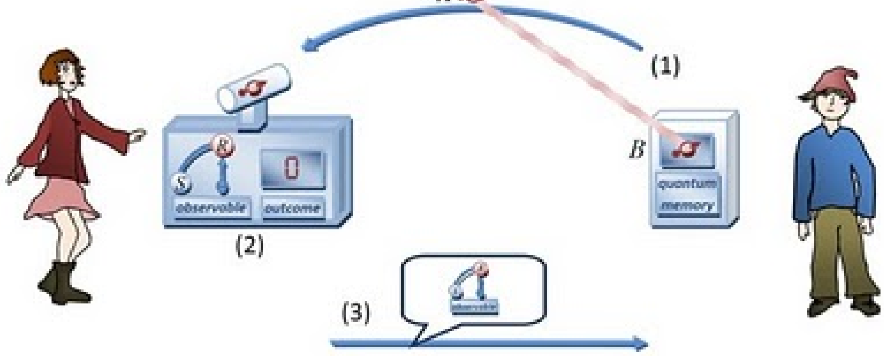
A Less Uncertain Uncertainty Principle

[From Left to Right] Mario Berta[1,2], Matthias Christandl[1,2], Roger Colbeck[1,3,4], Joseph M. Renes[5], Renato Renner[1] ; Affiliation: [1]Institute for Theoretical Physics, Zurich, Switzerland; [2]Faculty of Physics, Ludwig-Maximilians-Universität München, Munich, Germany; [3]Perimeter Institute for Theoretical Physics, Waterloo, Canada; [4]Institute of Theoretical Computer Science, Zurich, Switzerland; [5]Institute for Applied Physics, Technische Universität Darmstadt, Germany.

A recent paper published in Nature Physics by researchers from Canada, Germany and Switzerland has made Heisenberg's uncertainty principle — one of the central (and strangest) features in quantum physics — a lot less uncertain in some situations.

One question addressed by the uncertainty principle is whether it is possible to predict both the position and momentum (or other pairs of observables) of a subatomic particle. In its original formulation, the uncertainty principle implies that it is not. However, the paper shows that in the presence of quantum memory, a device capable of reliably storing quantum states, it is possible to predict both precisely. Intensive research efforts are currently focused on producing such a memory and there is hope that one will be available in the near future.

To illustrate the main ideas, the paper outlines an imaginary "uncertainty game" in which two people, Alice and Bob, begin by agreeing on two measurements, R and S, one of which will be performed. Bob then prepares a particle in a quantum state of his choosing. Without telling Alice what he has done, he sends the particle (over a channel) to Alice. Alice performs one of the two measurements (chosen at random) and tells Bob which observable she has measured, though not the measurement's value. Bob wants to correctly guess the measurement value. If Bob had only a classical memory (e.g. a piece of paper), he would not be able to guess correctly all of the time — this is what Heisenberg's uncertainty relation implies. However, if Bob is able to entangle the particle he sends with a quantum memory, for any measurement Alice makes on the particle, there is a measurement on Bob's memory that always gives him the same outcome. His uncertainty has vanished.



The paper provides a new uncertainty relation valid in the presence of a quantum memory. More precisely, it proves a lower bound on the uncertainties of the measurement outcomes which depends on the amount of entanglement between the measured particle and the quantum memory. This had been conjectured by J.C. Boileau and J.M. Renes in 2008 [2] but was unproven until recent work by Berta et al [1].

There are a number of potential applications arising from this work, notably for the burgeoning field of quantum cryptography. Although it was realized in the 1970s that the uncertainty principle could be used as the basis for ultra-secure communications, most quantum cryptographic approaches to date have not made use of it directly. The results may also yield a new method of 'witnessing' entanglement. Creating entangled states between particles (such as photons) is notoriously difficult, and once created, the states are easily destroyed by noise in the environment. A more straightforward witnessing method would be of great value to experimentalists striving to generate this precious resource, a necessary step towards developing quantum computers.

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[1] Mario Berta, Matthias Christandl, Roger Colbeck, Joseph M. Renes, Renato Renner, "The uncertainty principle in the presence of quantum memory", Nature Physics, published online July 25th, 2010. **Abstract**.
[2] Joseph M. Renes and Jean-Christian Boileau, "Conjectured Strong Complementary Information Tradeoff", Phys. Rev. Lett. 103, 020402 (2009). **Abstract**. **Arxiv-0806.3984**.

[We thank the Perimeter Institute for Theoretical Physics, Waterloo, Canada for materials used in this posting]

Labels: **Quantum Computation and Communication 3**

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*posted by Quark @ **8:43 AM***   **links to this post**

Sunday, August 22, 2010

Solving the Superconductor Puzzle

Thomas A. Maier [photo courtesy: Oak Ridge National Laboratory]

Superconducting materials, which transmit power resistance-free, are found to perform optimally when high- and low-charge density varies on the nanoscale level, according to research performed at the US Department of Energy's Oak Ridge National Laboratory (ORNL) and Institut für Theoretische Physik, Zürich, Switzerland.

In research toward better understanding the dynamics behind high-temperature superconductivity, the ORNL scientists rewrote computational code for the numerical Hubbard model that previously assumed copper-compound

Physics Related Quotes:

"There are 10^{11} stars in the galaxy. That used to be a huge number. But it's only a hundred billion. It's less than the national deficit! We used to call them astronomical numbers. Now we should call them economical numbers".
-- Richard Feynman

"All of physics is either impossible or trivial. It is impossible until you understand it, and then it becomes trivial."
-- Ernest Rutherford

"For all our conceits about being the center of the universe, we live in a routine planet of a humdrum star stuck away in an obscure corner ... on an unexceptional galaxy which is one of about 100 billion galaxies. ... That is the fundamental fact of the universe we inhabit, and it is very good for us to understand that."
-- Carl Sagan

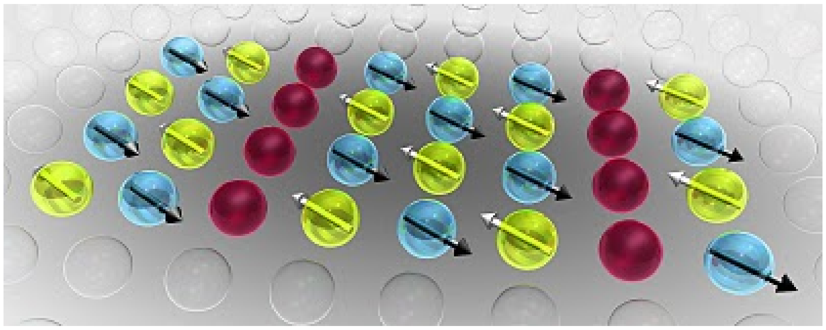
"Mathematicians do not study objects, but relations among objects; they are indifferent to the replacement of objects by others as long the relations don't change. Matter is not important, only form interests them."
-- Henri Poincare

"I think physicists are the Peter Pans of the human race. They never grow up and they keep their curiosity."
-- I.I. Rabi

"Far out in the uncharted backwaters of the unfashionable end of the Western Spiral arm of the Galaxy lies a small unregarded yellow sun. Orbiting this at a distance of roughly ninety-eight million miles is an utterly insignificant little blue-green planet whose ape-descended life forms are so amazingly primitive that they

superconducting materials known as cuprates to be homogenous — the same electron density — from atom to atom. The paper is published in Physical Review Letters [1].

Lead author Thomas Maier and colleagues Gonzalo Alvarez, Michael Summers and Thomas Schulthess received the Association for Computing Machinery Gordon Bell Prize two years ago for their high-performance computing application. The application has now been used to examine the nanoscale inhomogeneities in superconductors that had long been noticed but left unexplained.



Researchers have found that atom clusters with inhomogenous stripes of lower density (shown in red) raise critical temperature needed to reach superconductor state [Courtsey: ORNL]

"Cuprates and other chemical compounds used as superconductors require very cold temperatures, nearing absolute zero, to transition from a phase of resistance to no resistance," said Jack Wells, director of the Office of Institutional Planning and a former Computational Materials Sciences group leader.

Liquid nitrogen is used to cool superconductors into phase transition. The colder the conductive material has to get to reach the resistance-free superconductor phase, the less efficient and more costly are superconductor power infrastructures. Such infrastructures include those used on magnetic levitation trains, hospital Magnetic Resonance Imaging, particle accelerators and some city power utilities.

In angle-resolved photoemission experiments and transport studies on a cuprate material that exhibits striped electronic inhomogeneity, scientists for years observed that superconductivity is heavily affected by the nanoscale features and in some respect even optimized.

"The goal following the Gordon Bell Prize was to take that supercomputing application and learn whether these inhomogenous stripes increased or decreased the temperature required to reach transition," Wells said. "By discovering that striping leads to a strong increase in critical temperature, we can now ask the question: is there an optimal inhomogeneity?"

In an ideal world, a material could become superconductive at an easily achieved and maintained low temperature, eliminating much of the accompanying cost of the cooling infrastructure.

"The next step in our progress is a hard problem," Wells said. "But from our lab's point of view, all of the major tools suited for studying this phenomenon — the computational codes we've written, the neutron scattering experiments that allow us to examine nanoscale properties — are available to us here."

Reference

[1] T. A. Maier, G. Alvarez, M. Summers, T. C. Schulthess, "Dynamic Cluster Quantum Monte Carlo Simulations of a Two-Dimensional Hubbard Model with Stripelike Charge-Density-Wave Modulations: Interplay between Inhomogeneities and the Superconducting State", Phys. Rev. Lett. 104, 247001 (2010). **Abstract**.

[We thank Oak Ridge National Laboratory for materials used in this posting]

Labels: **Computational Physics**, **Condensed Matter 2**, **Nanotechnology 2**

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still think digital watches are a pretty neat idea."
-- Douglas Adams

"Space isn't remote at all. It's only an hour's drive away if your car could go straight upwards."
-- Fred Hoyle

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